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MARINE INDUSTRY STANDARDS
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INDUSTRIAL ENGINEERING
EDUCATION AND TRAINING

September 1982
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# THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

## Proceedings of the IREAPS Technical Symposium

## Paper No. 8: Modern Ship Repair Technology Applied to Naval Vessels

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

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## VOLUME I

INSTITUTE FOR RESEARCH AND ENGINEERING FOR AUTOMATION AND PRODUCTIVITY IN SHIPBUILDING

I R E A P S

# MODERN SHIP REPAIR TECHNOLOGY APPLIED TO NAVAL VESSELS

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Mr. Shoemaker has over twenty years shipbuilding experience in both new construction and repair. Major assignments have included new design work on CVN class reactor plants, and Q.A. engineering in a repair environment. He holds a Bachelor of Science degree in engineering technology from Old Dominion University.

## ABSTRACT

During the past several years the Maritime Administration has sponsored the National Shipbuilding Research Program (NSRP). The primary thrust of this program has been to identify those techniques which have enabled the Japanese to become world leaders in shipbuilding.

To date, the NSRP has been directed primarily toward new construction. However, in the Fall of 1981, Norfolk Naval Shipyard embarked on a program to adapt these techniques to the repair of naval ships. This effort is based on the Outfit Planning and Product Work Breakdown Structure methodology presented in the NSRP publications.

Further, a mini-computer system has been installed at Norfolk which allows schedules to be produced in a real-time manner. This system allows the shipyard to take full advantage of the NSRP techniques.

## 1. INTRODUCTION

The Naval industrial community has recognized that Naval shipyard productivity must be improved if we are to successfully meet the overhaul and repair needs of an expanded fleet. In-order to meet this challenge, Norfolk Naval Shipyard (NNSY) has focused on the proven shipyard techniques which have been developed under the Maritime Administration National Shipbuilding Research Program (NSRP). The NSRP publications, "Outfit Planning" and "Product Work Breakdown Structure", combined with a real time mini-computer system, form the basic framework for this effort.

To date, the primary thrust of the NSRP has been toward new construction; therefore, the challenge to NNSY is to adapt the new construction methodology to overhaul and repair work. Some Naval overhauls are larger in scope and manhours than many new construction contracts. Moreover, the complexity of overhaul work is increased due to the need to maintain portions of systems in an operable condition throughout the overhaul period.

## 2. BACKGROUND

### 2.1 Systems Orientation

Historically, all work in Naval Shipyards has been planned, scheduled, executed, and tested on a system by system basis. The system method has developed for several valid reasons which include:

- cost estimating
- cost accounting
- material estimating
- ship operation by system
- system test

Ship operators normally identify required work to a shipyard on a system basis. This method is acceptable and necessary to the shipyard for some categories. However, when the shipyard actually performs the repair work it is not done solely on a system by system basis. A close examination of any ship repair effort will show that work is planned, scheduled, executed and tested based on several criteria, one of which is the ship's functional systems. Other considerations must include:

- Geography, i.e., physical location of work
- Manpower required to perform work Availability of manpower
- Other work required to be performed in the same space
- Similar work to be performed in other areas of the ship
- Availability of material

All of these parameters are currently considered and resolved by shipyard management, usually the trade foreman or general foreman. These decisions are made on a trade by trade basis when the work is actually started. This method does not allow for an objective, analytical examination of the best possible way to perform the work. Neither does it provide a formal method of feedback, thereby increasing the corporate knowledge of the shipyard rather than the knowledge of the individual.

A further problem with the system by system approach is that the overall plan for completion of the overhaul is known, and fully understood only by a few individuals. Typically, these individuals are not the foremen and general foremen who are making the day to day waterfront decisions. For example, pipefitter and outside machinist foremen should not be expected to know all of the work to be performed in a given space. However, their decisions may directly impact upon the electrician's work. This often causes items to be installed in an improper sequence which results in unnecessary rework.

### 2.2 Zone Orientation

The work required for any large construction (or repair) project must be subdivided in order to be readily analyzed and managed. Any such subdivision scheme is a work breakdown structure.[1]

In order to subdivide repair work the "Zone Outfitting" and "Product Work Breakdown Structure" techniques published by the Maritime Administration have been closely examined. These techniques allow a repair yard to plan, schedule, execute and test production work in the manner in which it is actually performed i.e. across system and across trade boundaries. The work is broken into manageable blocks or zones which cross system and trade boundaries; and zone size may vary to suit the work at hand. A zone may be a single component or the entire ship. The zone concept of planning and scheduling allows the day to day decisions presently being made by waterfront foremen to be made at an earlier time in the overhaul, in a more objective manner. System by system planning is not eliminated by the zone technique. Indeed, sorting of work by system is in fact made easier and more meaningful when Zone Orientation is used.

### 2.3 Mini-Computer

As one explores the subdivision of a ship alteration/repair package beyond the traditional system by system approach, it becomes apparent that there is a significantly larger amount of information to be dealt with when using the PWBS technique. Unlike new construction, repair work must not only consider the production work and testing sequence, but must also consider those systems (or portion of systems) which must remain on-line throughout the overhaul.

In order to manage this large amount of information the need for a computer becomes readily apparent. Norfolk is attempting to use a relatively small mini-computer system for this effort. Our system is known as "PROMPT," an acronym for production oriented management planning technique, was developed by Science Applications, Inc., of La Jolla, California. The present hardware configuration includes a DEC PDP 11/44 processor with six CRT stations and a Printronix printer. PROMPT allows the sorting of detailed schedule information into various management reports. It futher provides a graphics capability which enables us to produce automated PERT schedules. We are presently using the PROMPT system to create working schedules at Norfolk.

## 3. PERTINENT TERMINOLOGY

3.1 Group Technology. Group technology applied to ship overhauls is the systematic grouping of similar repair processes to match common labor skills. Work is grouped by production process rather than by ship's systems.

3.2 Conventional Outfitting. Conventional outfitting is system by system outfitting. It is typified by allocations of resources to ship's systems and does not generally recognize interim subassembly of products, or the common production processes between systems.

3.3 Zone Outfitting. Zone outfitting is a technique which allows augmentation of the production process by classes of problems in order that common solutions can be applied to common problems. It is a means of organizing the work for better control and execution.

3.4 Zone. A zone is any subdivision of a ship which best serves for organizing information needed to support the ship at any stage of the overhaul.

3.4.1 Functional Zone. A functional zone is a subdivision of the ship which includes all equipment associated with a particular system or component. For example, a functional zone might include all piping and pumps associated with a particular tank, as well as the tank itself.

3.4.2 Geographical Zone. A geographical zone is a physical segment of the ship such as a complete deckhouse, a compartment, or portion of a compartment.

3.4.3 Variable Zone. A variable zone is a combination of functional zone and geographical zone which organizes the work by process. It is the zone in which the work is to be done and may include more than one functional and geographical zone. It is also known as a work zone.

3.5 Pallet as a Work Package. Literally a pallet is a portable platform upon which materials are stacked for storage or transportation. The term pallet is also used to indicate a work package. It represents a definite increment of work with allocated resources needed to perform the defined overhaul activity. A pallet is therefore organized by work zone and stage of the overhaul.

3.6 Palletizing. Palletizing is the creation of a work package including job definition, location, software, resource definitions and material definition. It includes integration of zones and processes to achieve an optimum flow of people past the required work.

3.7 Stage. A stage is a band of time during an overhaul in which specific production processes take place. Examples include:

- Prearrival planning/engineering
- Prefabrication
- Disassembly (ripout)
- Open and inspect (replanning)
- Repair
- On-unit assembly
- On-block assembly
- On-board assembly
- Test

3.8 Problem Area. A problem area is an aspect of a particular job which is unique, and therefore requires special categorization. A specialty within a trade is the most common example. However, problem area may also be due to quantity (large or small) of similar operations, location of the operation, or type of operations (i.e., manufacturing vice assembly).

## 4. PRODUCT WORK BREAKDOWN STRUCTURE

4.1 General. The work required for any large repair project must be subdivided in order to be effectively analyzed and managed.[1] Traditionally, this subdivision has been by ship's functional systems. System orientation is desirable for estimating and early planning. However, system orientation for production planning, scheduling, and execution is inappropriate since it does not reflect the way the work is actually performed. Product Work Breakdown Structure (PWBS) provides a scheme to subdivide the repair/overhaul tasks in the manner in which they are actually conducted.

### 4.2 System Vice Zone Orientation

4.2.1 Schedules. Historically, schedules at NNSY have been drawn on a system by system basis. This technique results in a series of parallel lines which, in theory, are interconnected at each system interface. In practice, the interfaces are insufficient either because they are not properly thought out originally; or because they are lost during revisions to the schedule. Therefore, the end product is a series of parallel lines indicating activities which may, or may not, be interdependent.

In order to resolve this problem the shipyard has turned to PERT type schedules which clearly show interfacing activities. However, the complexity of creating and revising hand drawn PERT schedules is overwhelming. Therefore, it becomes necessary to have a system for creating and/or revising a PERT schedule using ADP equipment.

4.2.2 Job Orders/Work Orders. Job orders, work orders, and procedures, i.e., the paper by which the trades do work, are also written on a system by system basis. A further breakdown usually identifies the job to a lead or cognizant trade. The paper does not usually identify similar work taking place on the same ship, or adjacent/interface work. This results in the real Production Department decisions, such as which tasks to perform together, and when to perform the tasks, being made by each individual trade. While trade supervisors attempt to be objective, it is not unusual for work to be performed on a "first one in" basis. This often results in trade conflicts such as ripout of newly installed items.

### 4.3 PWBS for Overhaul/Repair

4.3.1 PWBS Decisions. To date, PWBS techniques have been applied only to new construction. Figure 4-l has been developed to provide a guide for making PWBS decisions in an overhaul environment. Figure 4-l allows the work to be subdivided categorically by zone, problem area (specialty) and stage. Each category is then examined in relation to the other two. Using this technique it is possible to create a virtual flowlane for the required work. A virtual flowlane may be thought of as an assembly line in which people flow by the work. The virtual flowlane optimizes use of production time by minimizing set up time between jobs of similar skill, and by ensuring that the best possible environment exists when the cognizant trade arrives at the job site. The environment created will provide a safe workplace in which all needed materials are on hand, and all interfacing work has been considered and properly sequenced.

4.3.2 Productivity Measurement. Upon completion of the PWBS analysis described in section 4.3.1 it becomes apparent that one is able to assign a productivity value, or product resource value, to each of the defined tasks. This value will be categorized under the general heading of one of the following.[1]

- Material, to be used for production, either direct or indirect, e.g., steel plate, machinery, cable, oil, etc.

- Manpower, to be charged for production, either direct or indirect, e.g., welder, gas cutter, fitter, finisher, rigger, material arranger, transporter, etc.

- Facilities, to be applied for production, either direct or indirect, e.g., docks, machinery, equipments, tools, etc.

- Expenses, to be charged for production, either direct or indirect, e.g., designing, transportation, sea trials, ceremonies, etc.

Upon assignment of the product resource value it is possible to analyze the availability of resources for each category and determine the impact on the overall performance of work.

## 5. PROMPT SCHEDULING SYSTEM

5.1 General. In order to effectively apply the PWBS technique it is highly desireable to have a real time, interactive scheduling system. Norfolk Naval Shipyard is using the PROMPT System to meet this need. PROMPT was developed by Science Application, Inc. (SAI) of La Jolla, California. To develop this system SAI drew upon hardware and software from similar government applications, and combined these with additional software to provide a dynamic, interactive scheduling system. The system provides integrated schedules at various levels of detail, and allows information to be updated, progressed or modified as required via an on-line interactive terminal.

The present system at NNSY consists of a DEC PDP 11/44 mini-computer with six CRT terminals. The system is operated on a day-to-day basis by scheduling section personnel, and is presently used to create and/or modify PERT chart schedules at various levels of detail.

5.2 Hierarchical Schedules. Shipyard production schedules form the framework for the flow of information between various shipyard functions. Moreover, schedules are the control mechanisms by which planned work packages are conveyed to the work force,.[2] In order to be meaningful to the intended user, the schedule should generally be presented at the level of detail which corresponds to the user's responsibility. For example, the major key event schedule of an overhaul may be interesting to a first line waterfront foreman; however, his real need is a day-to-day sequence of the tasks he must accomplish.

In ‘order to meet the needs of senior management, middle management, and first line supervision NNSY has chosen a top down method of scheduling. Schedules are developed by determining the ship availability dates, the major milestones, key events and so forth. This process is carried to the lowest level necessary which may be a list of jobs, or a list of tasks within a specific job.

The PROMPT system allows six levels of schedules. Schedules are linked between levels through individual activities. Each of the networks in this hierarchical arrangement is a sub-network which relates to the overall repair plan.

5.3 Schedules by Zone. In order to be meaningful, schedules must indicate the sequence in which work is to be accomplished. The schedule must show all system and trade interdependencies. These fundamental requirements have resulted in three scheduling zones at NNSY. These zones form the basic framework by which the scheduling decisions are made.

5.3.1 Functional Zone. This level of schedule depicts the system functional requirements as they relate to the jobs required to be performed. This schedule creates the basic "windows" in which work may be performed. These windows reflect which systems, or portions of systems, are required to be on line during the overhaul.

5.3.2 Geographical Zone. The geographical zone is simply the physical location of the job aboard ship. Ideally, the jobs are indicated on a composite drawing. However, since-composite drawings are generally not available to an overhaul yard, a "make do" composite is created from the ship's arrangment drawing. There is presently some interest at NNSY in creating composite drawings using photogrammetry. However, this interest has not yet been developed to the prototype stage.

5.3.3 Variable Zone. The variable zone may be thought of as the work zone. It is a union of the functional zone and the geographical zone by the process to be performed.

5.4 Test Schedule. Traditionally, the schedule for testing of ship's systems has been independent from the production schedule. Using the PROMPT system, it is desirable to integrate system tests with production work to the maximum extent possible. This allows testing to take place in the earliest possible window established by the functional zone.

5.5 Progress Reporting/Rescheduling. In order for a real time scheduling system to be effective throughout an overhaul it must have the capability to reflect the status of each job in a timely manner. PROMPT allows the user to enter job progress on a periodic basis (the time period is selected by the user). Upon entry of progress, it is possible to determine impact on the remainder of the network being progressed; and, on netowrks of a higher level. This feature enables the user to reschedule work as the situation changes. Moreover, impact of late finishes or earlier finishes of events may be immediately analyzed and the "best path" to job completion determined.

The real time capability of PROMPT allows the shipyard to perform 'what if' studies in a much easier manner than previously possible. However, yard management has found that while this increased capability is a great advantage, projects must be thoroughly examined prior to initiation in order to efficiently utilize PROMPT resources.

5.6 Management Reports. With the large amount of data stored, in PROMPT it is possible to develop many different management reports. These reports include the following which are adequately described by their title:

- Milestone Report
- Schedule Report
- Work Status and Progress Report
- List of Active Projects

Additional reports include:

a. Bar Graph Report or Gantt Chart which graphically illustrates the scheduled duration of each work item, a Precedence Report which lists all work items in the network and identifies each preceding work item, a Calendar Report which provides a calendar of the network period including those days which the user has declared as holidays, and a Master File Report which is a printout of PROMPT created scheduling files.

## 6. EXAMPLE

6.1 General. The best method to illustrate the concepts previously presented is with an example. Figure 6.1 shows a plan view of the hypothetical ship to be overhauled. Figure 6.2 shows the same ship, with a functional zone representing the Firemain System in the forward portion of the ship. Figure 6.3 shows the first cut at geographical zoning which includes the port Auxiliary Machinery Room, and one half of the Main Machinery Room. The variable zone, or work zone, is shown in Figure 6.4. This work zone has been determined by analyzing all work in the machinery space using the PWBS system.

6.2 Specific Jobs. For the purpose of this example assume that the following specific jobs are to be performed in the variable zone shown in Figure 6.4.

JOB ORDERS

1. Replace 9'-0 level grating
2. Replace firemain piping FR 100-102
3. Replace demineralized water pump and motor
4. Calibrate gauges system 1
5. Calibrate gauges system 2
6. Calibrate gauges system 3
7. Add light frame 103-104 S/A 1000
8. Renew pipe and valve main feed system FR 100-102
9. Add vent duct S/A 2000
10. Open/inspect/repair valves system 1
11. Open/inspect/repair valves system 2
12. Open/inspect/repair valves system 3
13. Open/inspect/repair valves system 4
14. Open/inspect/repair valves system 5
15. Add shock support and modify demin water pump foundation S/A 3000

6.3 Tasks Required. In order to accomplish the jobs listed in section 6.2 the tasks shown below must be ‘performed. Thse tasks have been organized by stage; i.e., Planning and Engineering, Procurement, Open and Inspect, Secondary

Procurement, Repair, On Unit Assembly, On Board Assembly. This has been done by proceeding through the PWBS process as outlined in Figure 4.1, which results in the breakdown of:

## PLANNING AND ENGINEERING

Define jobs from customer.
Perform production planning.
Write job orders or procedures.
Define material
Schedule work

## PROCUREMENT

Procure material and fabricate demin water pump foundation.
Procure material and fabricate main feed system pipe.
Procure material and fabricate fire main system pipe.
Procure material and fabricate vent duct.
Procure material and fabricate light assembly.

## RIPOUT

Remove insulation
Remove demineralized water pump and motor
Remove MN feed pipe assy
Remove 9' -0 level grating and demin water pump FND
Remove AUX salt water PPG
Remove fire main
Remove gauges
Remove 6" demin water pipe FR 100-103
Install temp staging @ 9' -0 LVL
Cut temp access

## OPEN AND INSPECT

Open/inspect system 1, 2, 3 valves, flow path A
Open/inspect system 1, 2, 3 valves, flow path B
Open/inspect system 1, 2, 3 valves, flow path C
Open/inspect system 4 & 5 flow path B
Open/inspect system 4 & 5 flow path C

## SECONDARY PROCUREMENT AND REPAIR

Procure material identified by open and inspect stage.

## REPAIR/ALTERATION

Perform all repairs and alteration work aboard ship and off ship such as valve lapping, component maintenance, etc.

ON UNIT

Assemble demineralized water pump unit

ON BOARD

Reassemble system 1, 2, 3 valves flow path A
Reassemble system 1, 2, 3 valves flow path B
Reassemble system 1, 2, 3 valves flow path C
Reassemble system 4 & 5 valves flow path B
Reassemble system 4 & 5 valves flow path C
Reinstall system 1 gauge, flow path A
Reinstall system 1 gauge, flow path B
Reinstall system 1 gauge, flow path C
Install vent duct
Install MN feed pipe assy
Install fire main piping assy
Reinstall ASW piping
Install demin water pump unit and connect pipe
Remove staging Clean and paint bilge
Install 9' -0 LVL grating
Close access cuts
Install light
Relag MN FD and demin water PPG ABV 9' -0 LVL
Clean and paint 9' -0 LVL to 22' LVL

Once the PWBS technique has been completed a PERT schedule for the tasks is generated, a portion of which is shown in Figure 6.5. The schedule is then progressed, and tasks are rescheduled *as* necessary, as work progresses.

## 7. EXPECTED PRODUCTIVITY IMPROVEMENTS

7.1 Current Improvements. Presently, the PROMPT system is in use for planning and scheduling of a complex overhaul of the propulsion plant on a CGN. Schedules have been produced with the computer which have resulted in a significant savings in the manual drafting time previously required to produce a schedule. However, greater savings have been achieved when it has become necessary to revise PROMPT schedules. A revision with PROMPT takes only minutes, where the hand drawn revision would take days.

7.2 Expected Improvements. While there have been productivity improvements in scheduling, the greatest improvement is expected in the Production Department waterfront trades. The virtual flow lanes created by the PWBS process will produce an efficient use of trade resources in that work will be performed in an orderly manner which has been thought through objectively prior to arrival of the cognizant trade at the job site.

1. "National Shipbuilding Research Program - Product Work Breakdown Structure" U.S. Dept. of Commerce, Maritime Administration

2. "National Shipbuilding Research Program - Outfit Planning" U.S. Department of Commerce, Maritime Administration

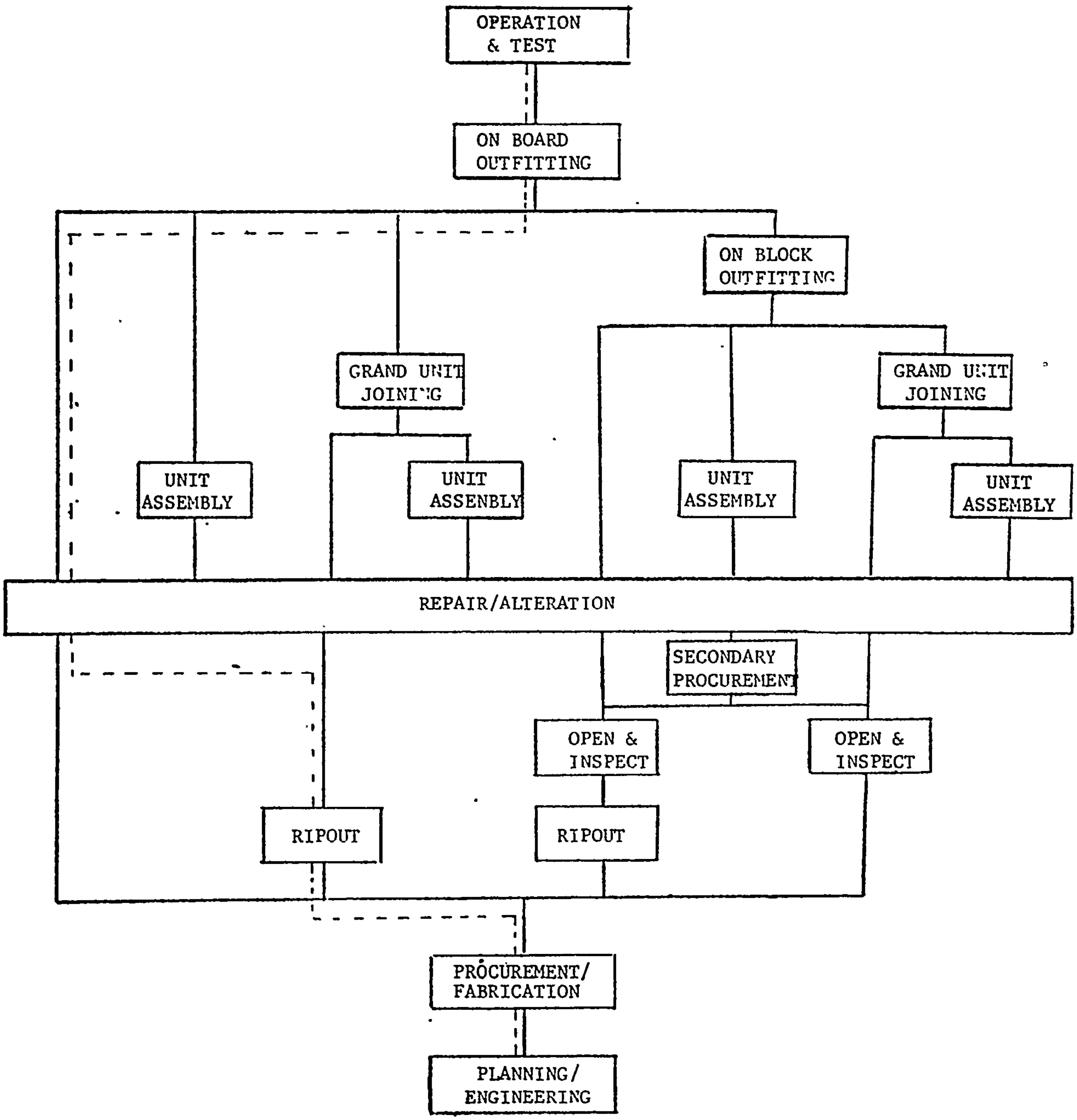



FIGURE 4.1
SH 1

| PRODUCT ASPECTS | | |
|---|---|---|
| ZONE | PROBLEM AREA | STAGE |
| SHIP | DECK<br>ACCOM.<br>MACH<br>NUCLEAR<br>ELECT.<br>ELEX/WEAP | OPERATION & TEST |
| ON BOARD DIVERSION | SIMILAR WORK IN SML VOL.<br>SIMILAR WORK IN LRG VOL.<br>SIMILAR WORK IN HIGH SKILL | REASSEMBLY |
| BLOCK | COMPONENT IN LARGE QUANTITY<br>COMPONENT IN SMALL QUANTITY | REASSEMBLY |
| GRAND UNIT | LARGE UNIT | WELDING<br>UNIT JOINING |
| UNIT | LARGE SIZE UNIT<br>SMALL SIZE UNIT | WELDING<br>ASSEMBLY |
| COMPONENT | LARGE/ SMALL QUANTITY<br>SPEC- IALTY<br>INTER- FACES | |
| ON BOARD DIVERSION | BY SPEC- IALTY<br>ITEMS IN LARGE/ SMALL QUANTITY | INSPECT/REPORT<br>DISASSEMBLY |
| ON BOARD DIVERSION | BY SPEC- IALTY<br>ITEMS IN LARGE/SML QUANTITY<br>INTERF. | SORTING (DEPALLETIZING)<br>DISASSEMBLY |
| COMPONENT | IN HOUSE MANUFAC<br>OUTSIDE MANUFAC<br>BUY<br>REQ. FROM STOCK | PALLETIZING<br>MANUFACTURING<br>MAT'L REQ. DEFINITION |
| SHIP | DECK<br>ACCOM.<br>MACH<br>NUCLEAR<br>ELECT<br>ELEC/WEAPS | PREARRIVAL INSP. REPORT<br>SHIPALTS<br>TECH WORK DOC. |

FIGURE 4. 1
SH 2

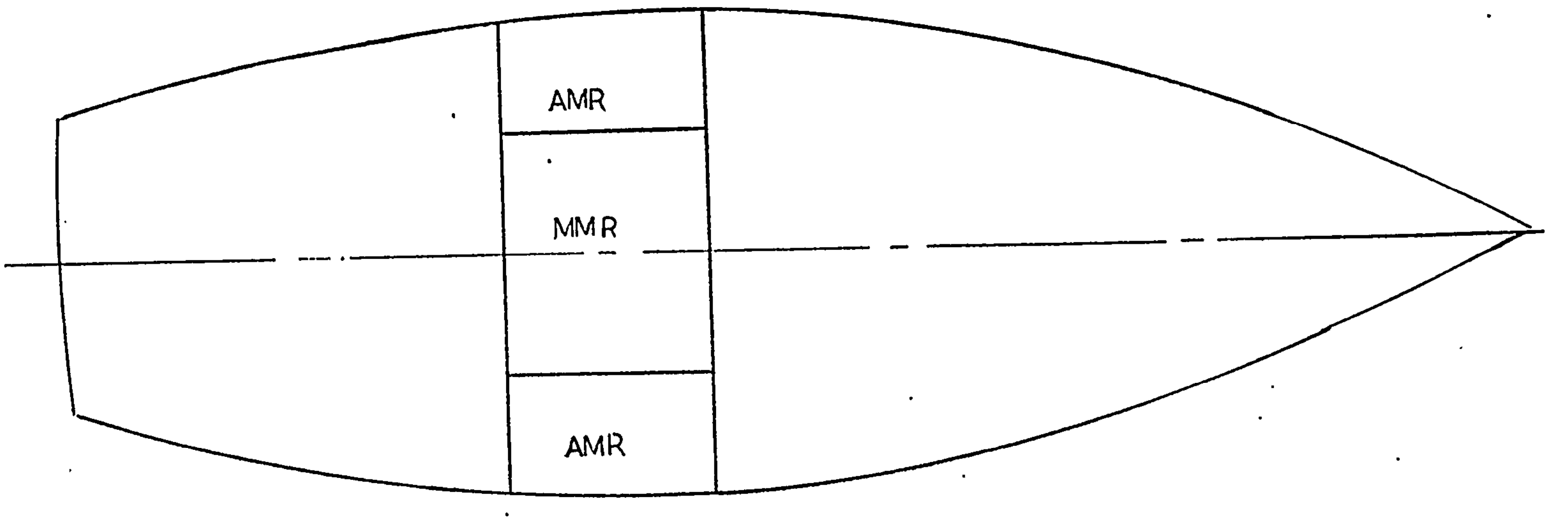



FIGURE 6.1

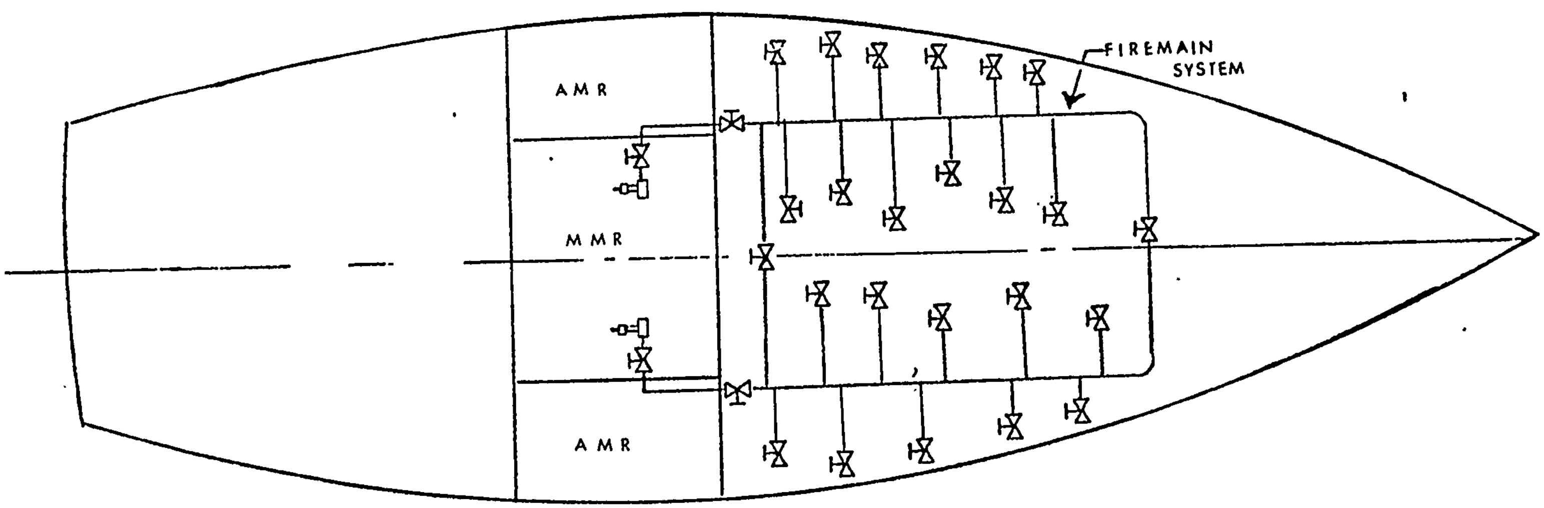



FIGURE 6.2

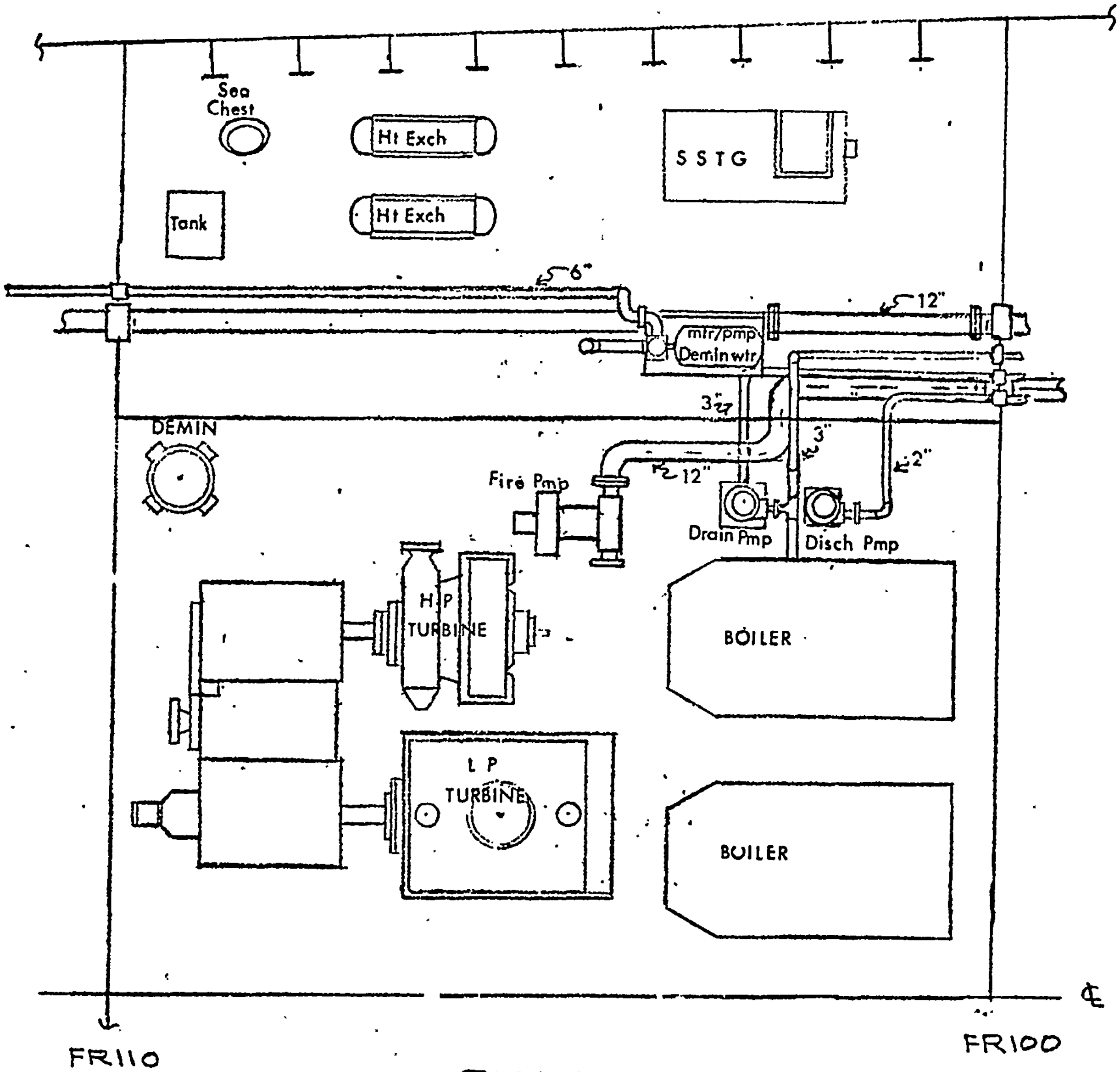
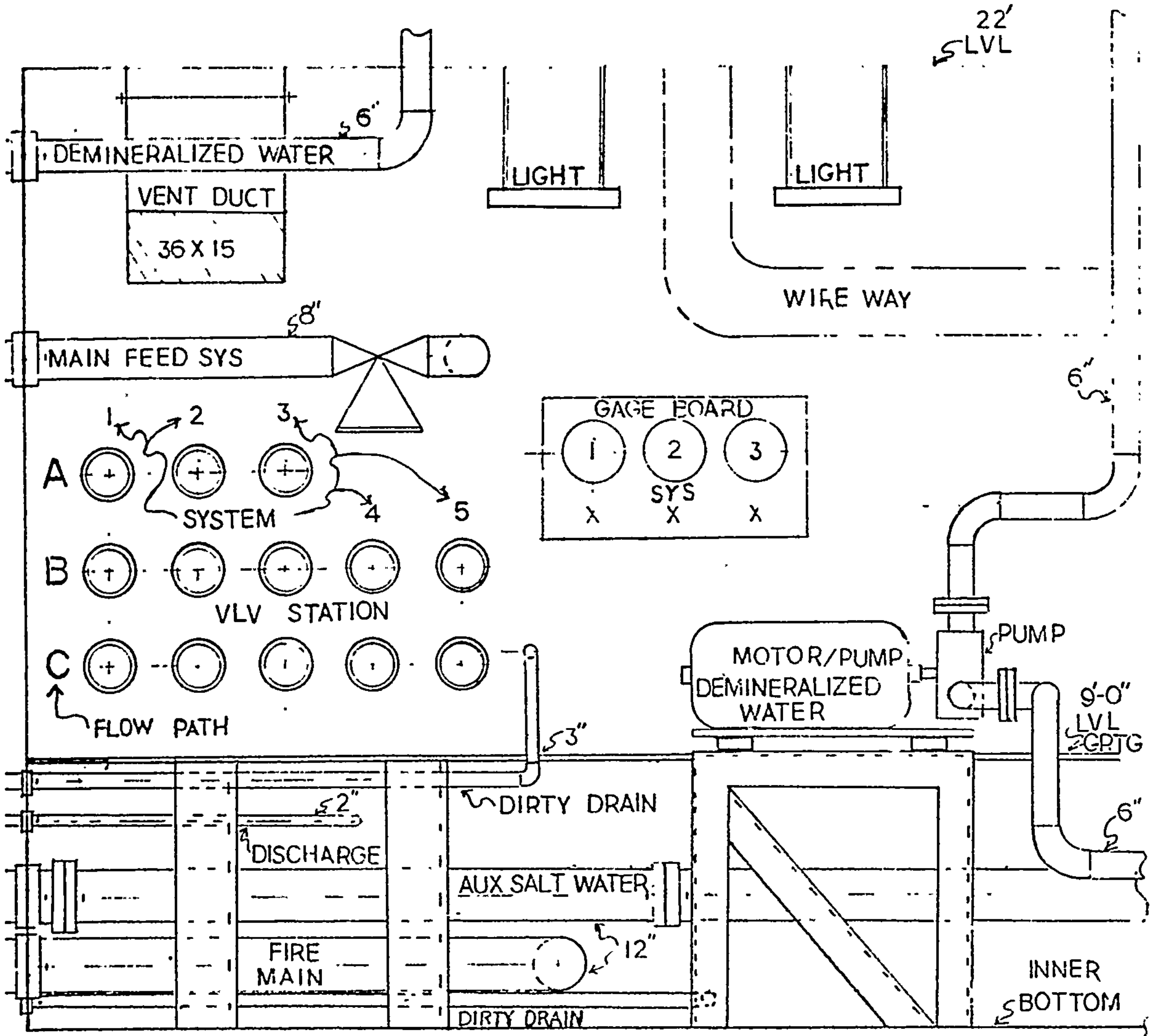



FIGURE 6.3

PLAN

FWD →




ELEVATION (LKG INBD)

FIGURE 6.4

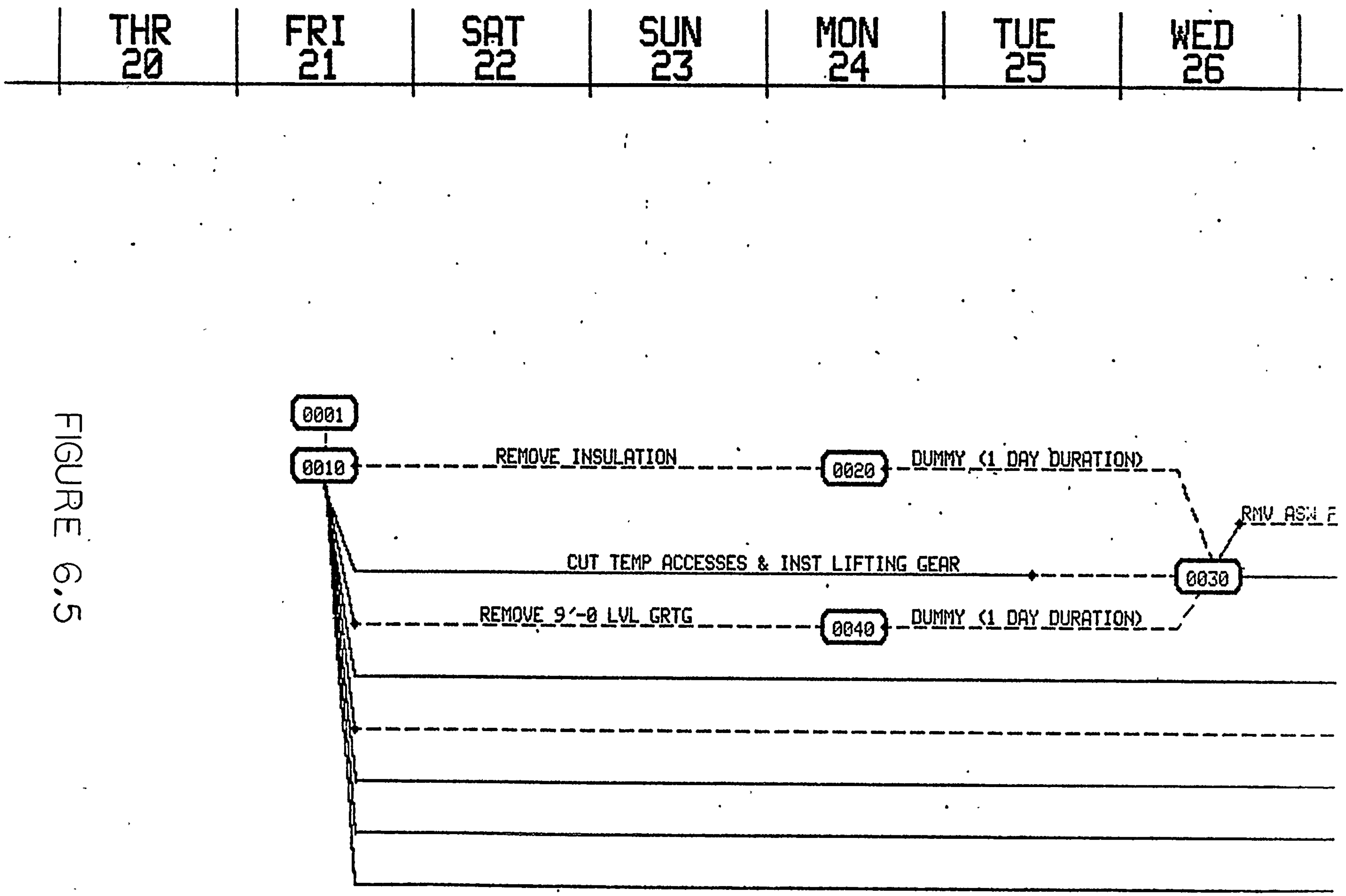

THR 20
FRI 21
SAT 22
SUN 23
MON 24
TUE 25
WED 26
0001
0010
REMOVE INSULATION
0020
DUMMY (1 DAY DURATION)
RMV ASW F
CUT TEMP ACCESSES & INST LIFTING GEAR
0030
REMOVE 9'-0 LVL GRTG
0040
DUMMY (1 DAY DURATION)

FIGURE 6.5

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